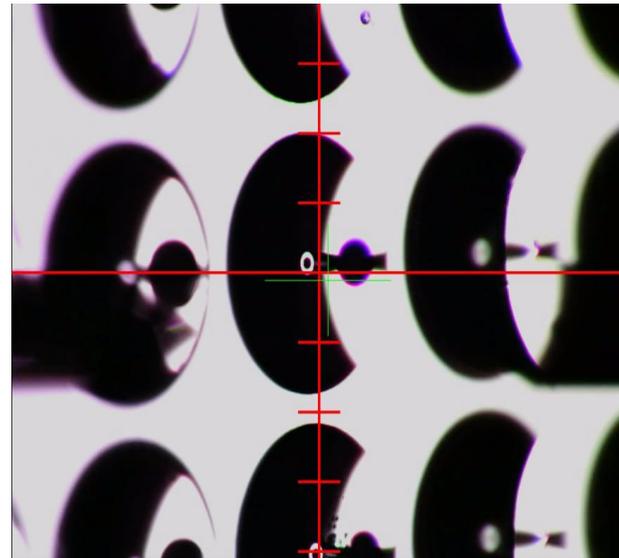
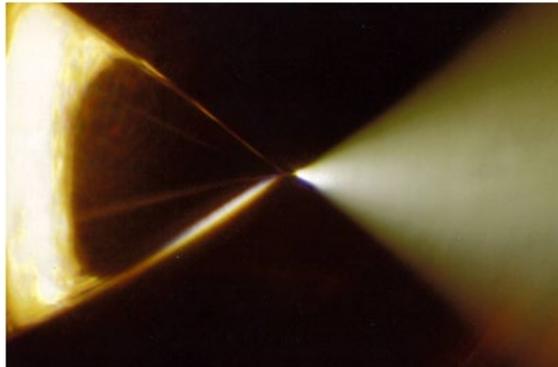




# Variable Specific Impulse Electrospray Thrusters for SmallSat Propulsion

Prof. Manuel Gamero-Castaño  
Dr. Albert Cisquilla-Serra  
Marc Galobardes-Esteban



**Cooperative Agreement (CA) #: 80NSSC20M0084**  
**NASA Support: Jet Propulsion Laboratory**



## Propulsion is an enabling technology for many SmallSat missions

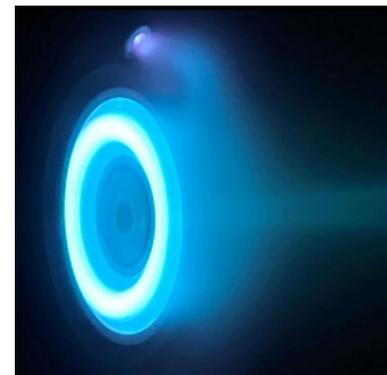
Propulsion system is essential for:

- Orbit insertion (beyond initial deployment orbit)
- Orbit maneuvering and maintenance
- SmallSat constellations (insertion, maneuvering, maintenance, redeployment)
- Deorbit



Propulsion system must be:

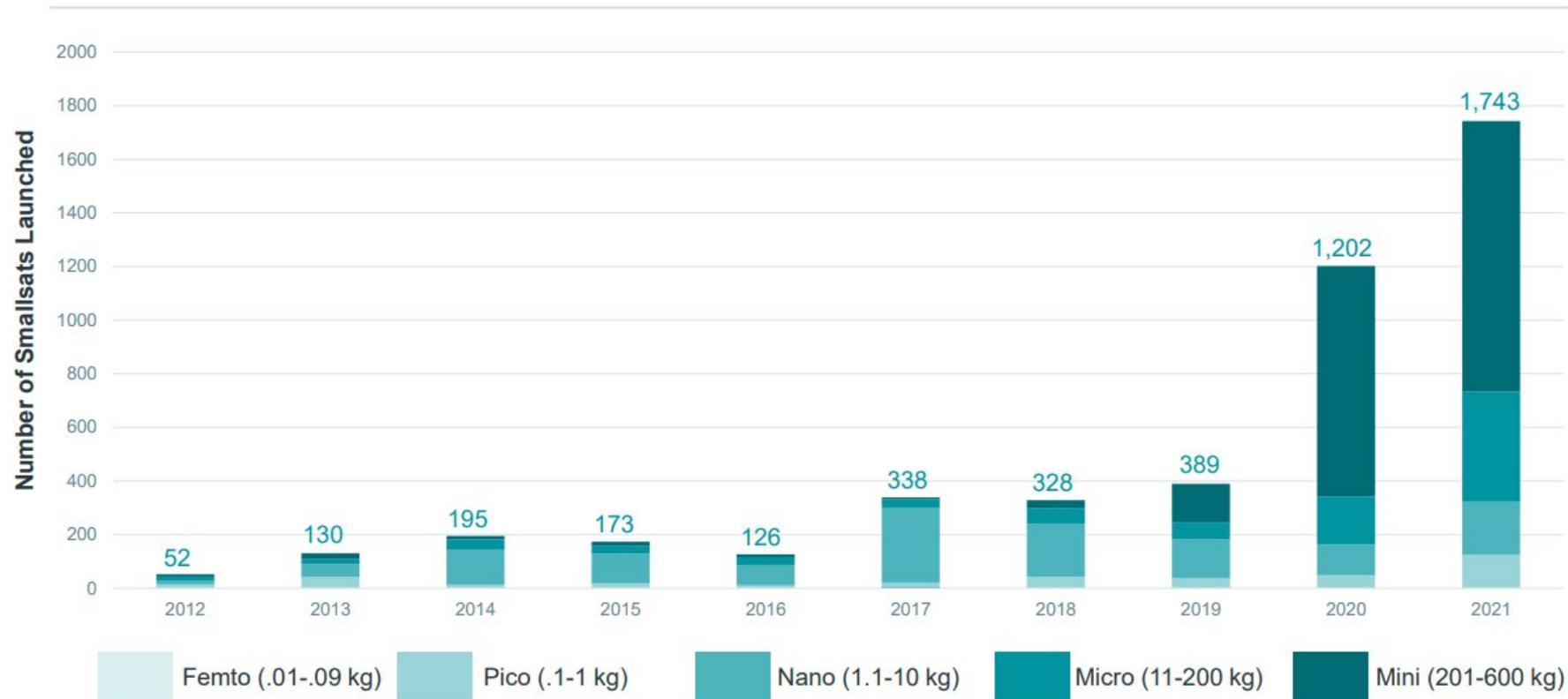
- compatible with SmallSats' reduced mass and volume budget
- Efficient at low available power
- Scalable to operate throughout SmallSats power range and thrusting needs (primary propulsion and attitude control)



Plasma discharge thrusters cannot be scaled down to the power levels typical of SmallSats



## Evolution of annual number of launched SmallSats







## Electropray propulsion is an ideal technology for SmallSats

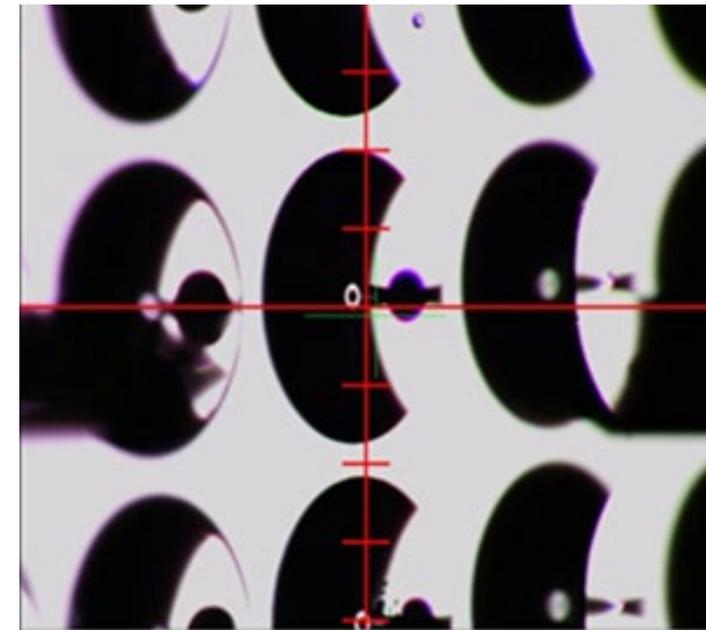
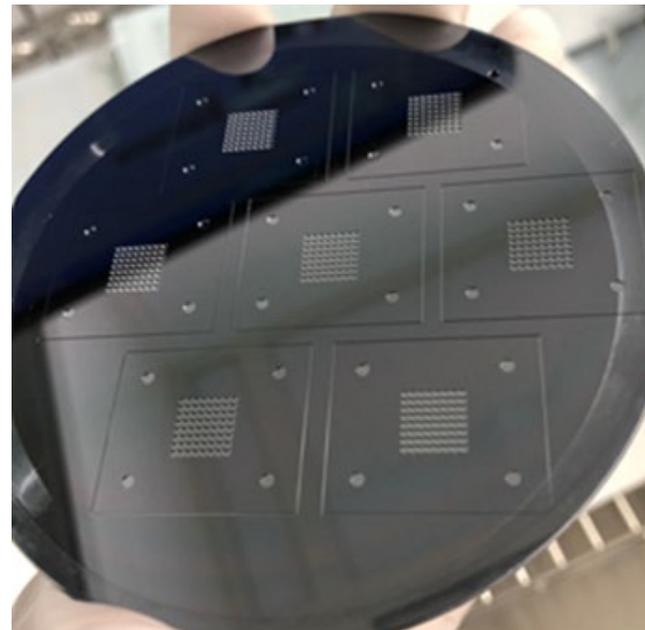
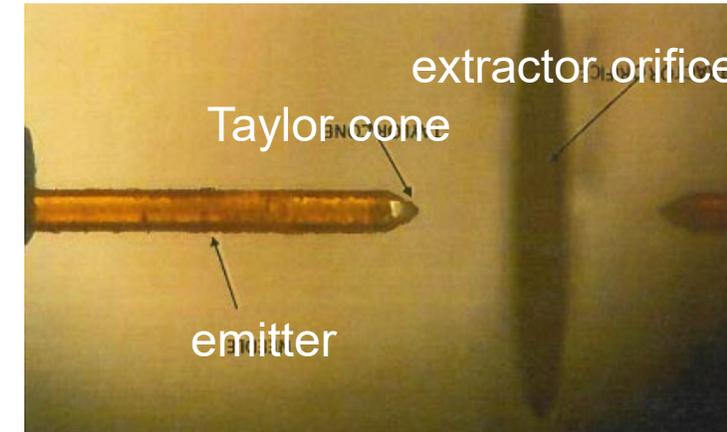
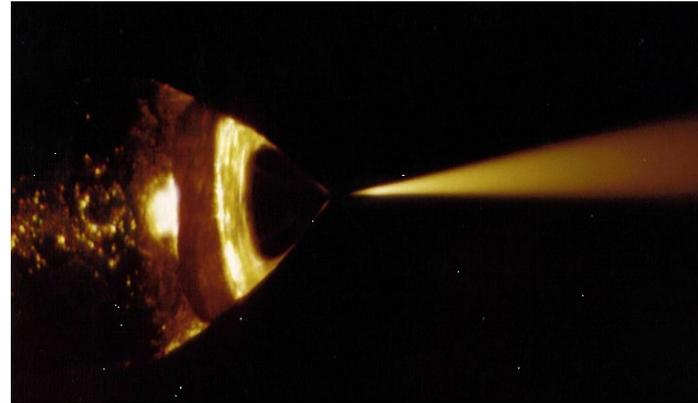
A single emitter atomizes a liquid propellant into charged droplets/ions, which are accelerated by an electrostatic field. Typical propulsive parameters per emitter:

- Thrust  $\cong 0.5 \mu\text{N}$
- Power  $\cong 1 \text{ mW}$
- Efficiency  $\cong 68\%$

*Gamero and Hruby, 2001*

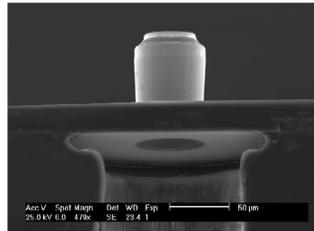
Thruster is scalable with the help of micromachining (micromachined emitter arrays):

- Very high emitter density
- Variable emitter array size can deliver all power/thrusting levels of SmallSats (scalability)

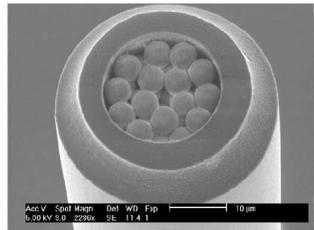




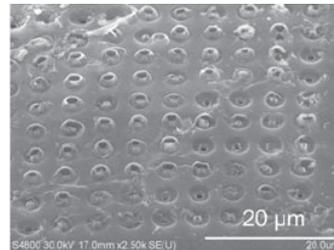
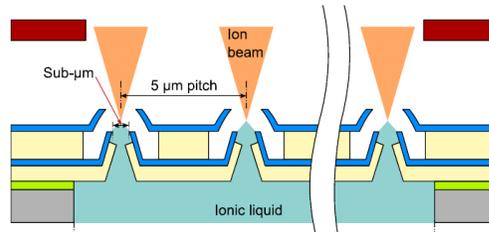
## Internally wetted emitters



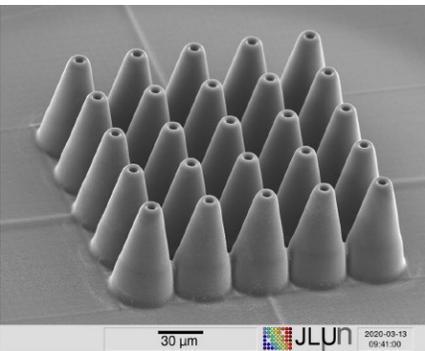
(a)



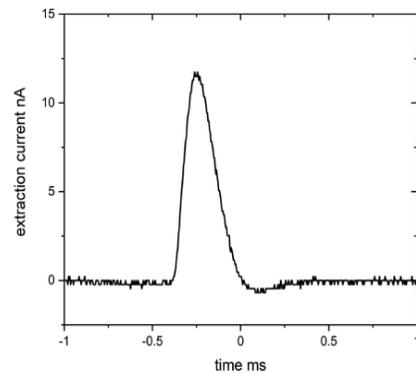
*R Krpoun et al., 2009*



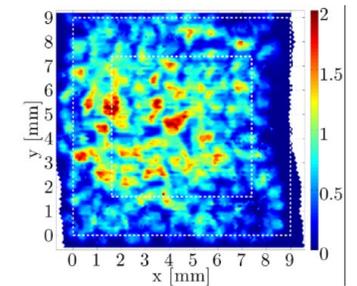
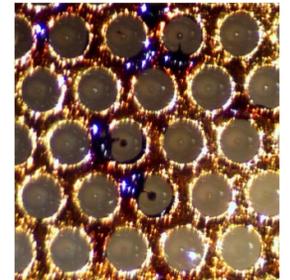
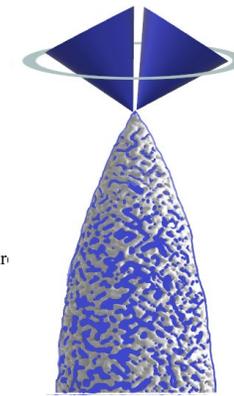
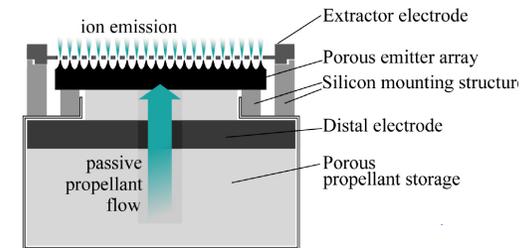
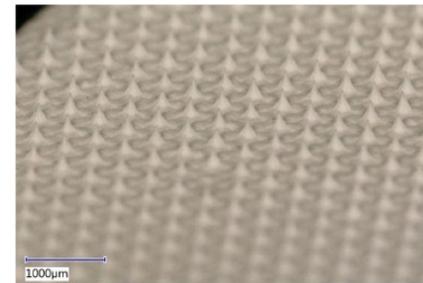
*Inoue et al., 2019*



*Kunze et al., 2021*



## Externally wetted emitters

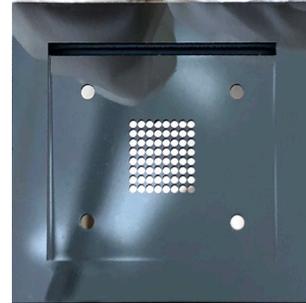
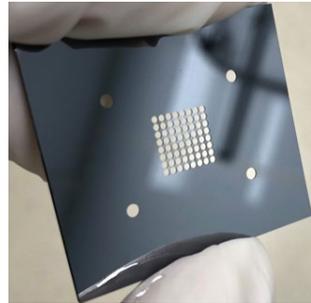
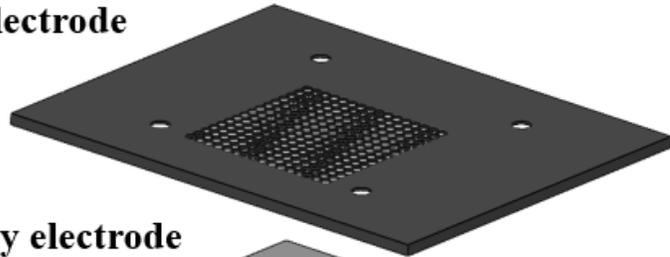


*Krejci et al., 2017*

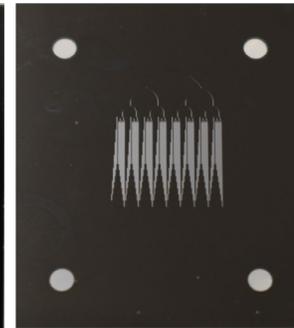
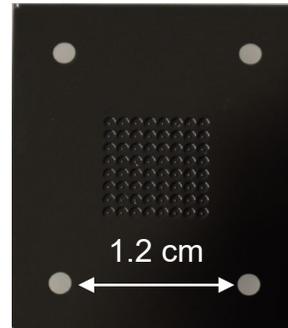
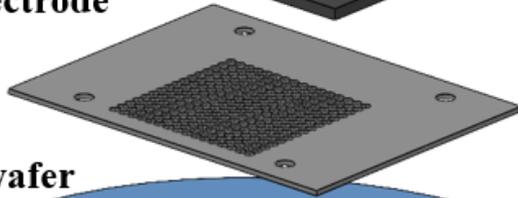


## Microfabrication on Si and glass wafers

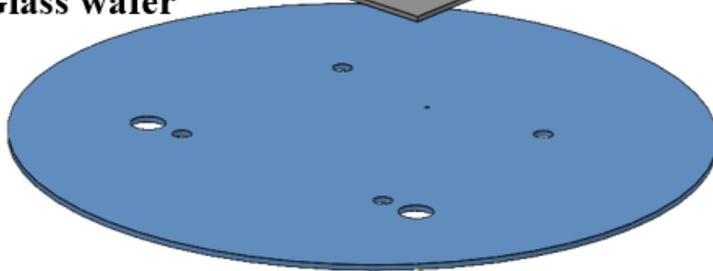
**Extractor electrode**



**Emitter array electrode**



**Borofloat Glass wafer**

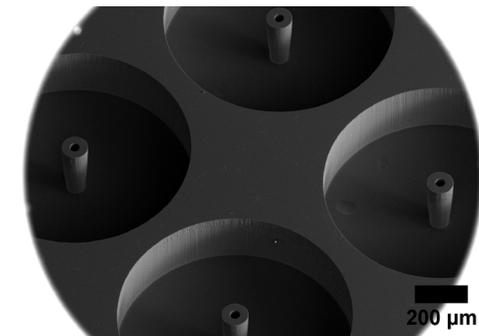
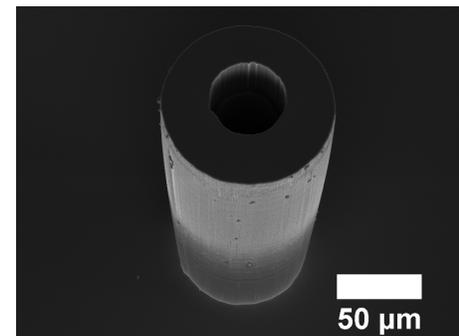
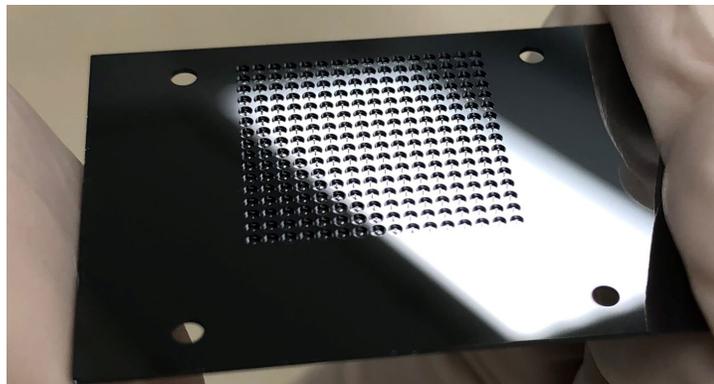
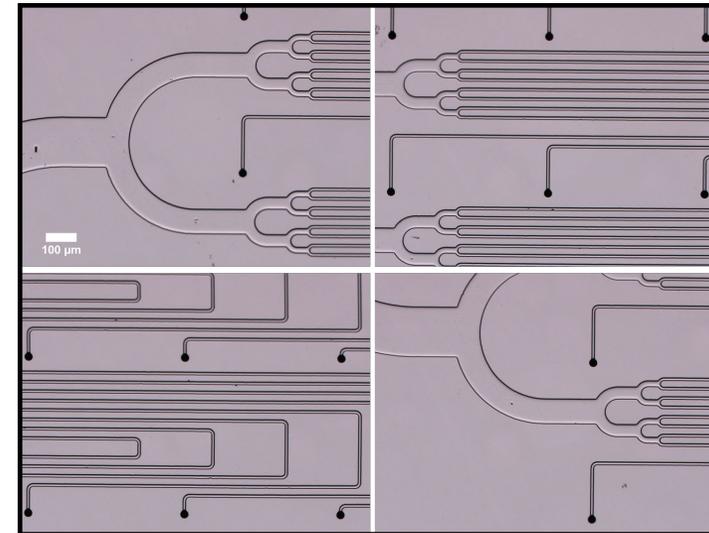
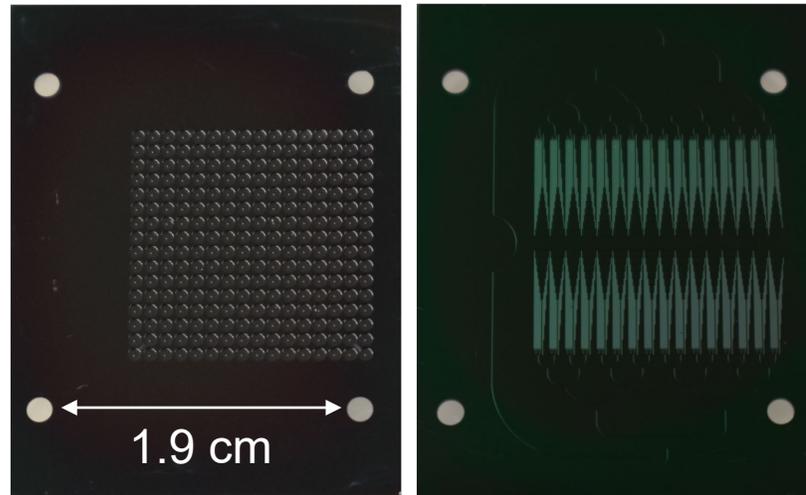


**Fused Silica Line**



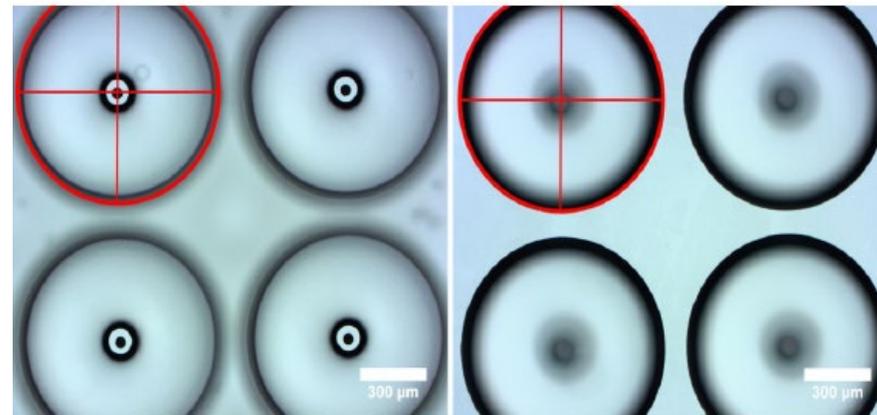
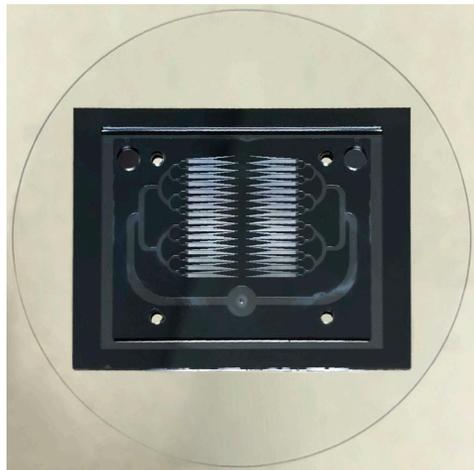
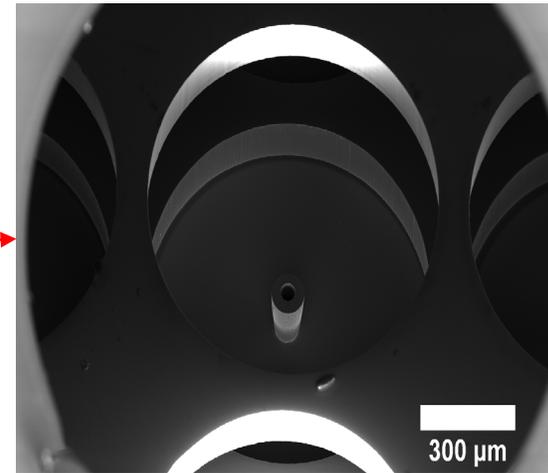
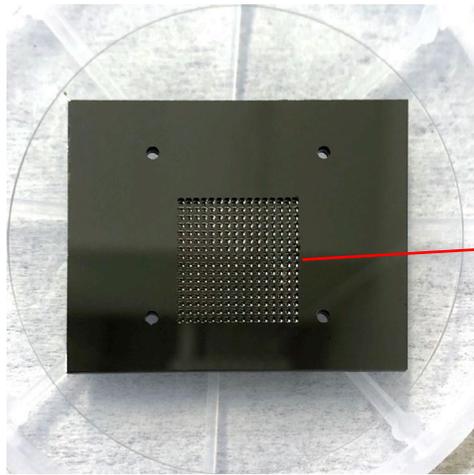


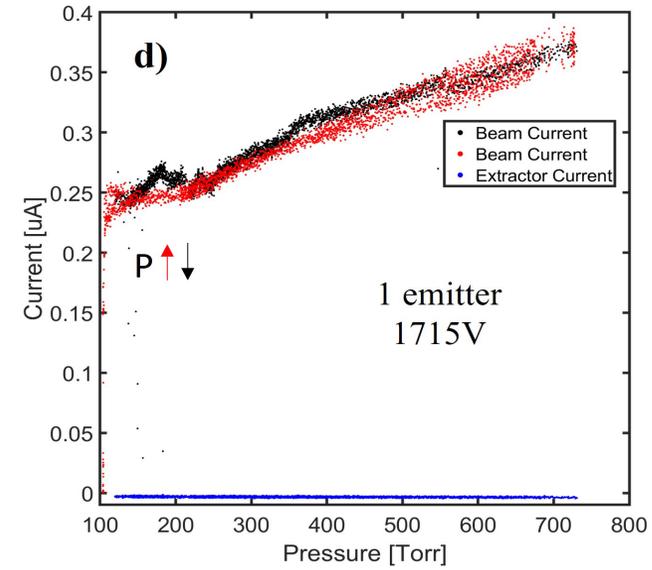
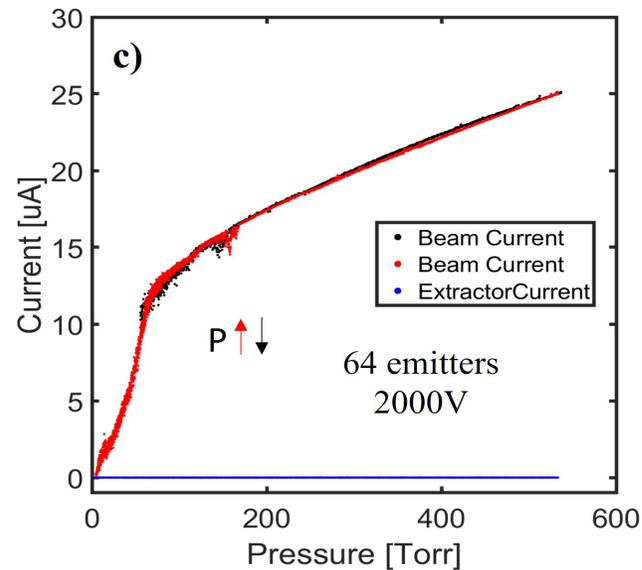
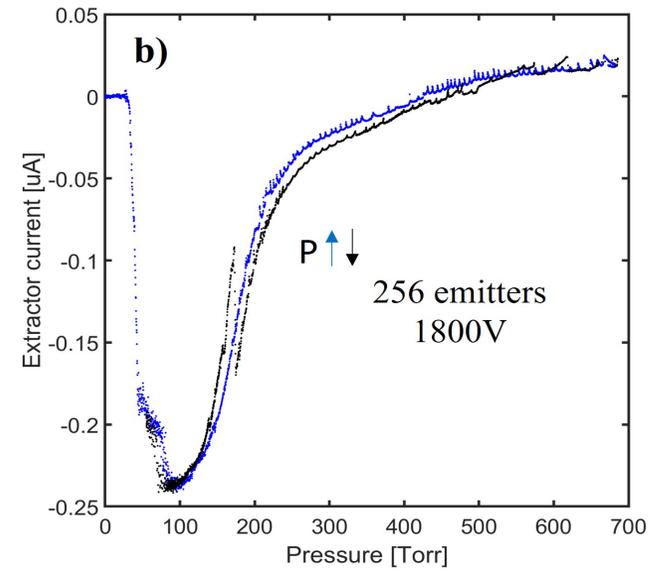
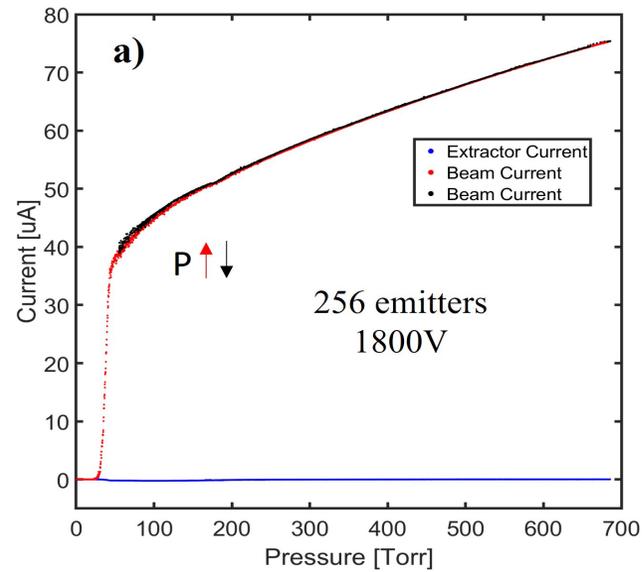
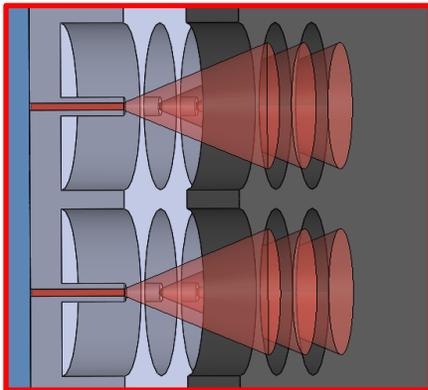
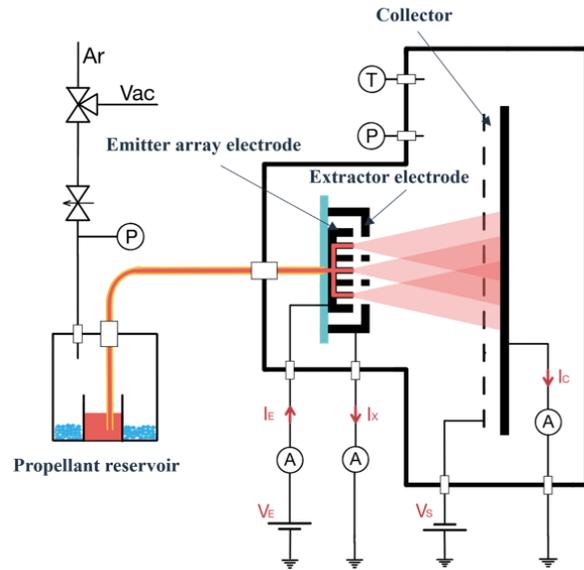
## Internally wetted emitter arrays with network of microfluidic channels matching emitters (excellent flow regulation)

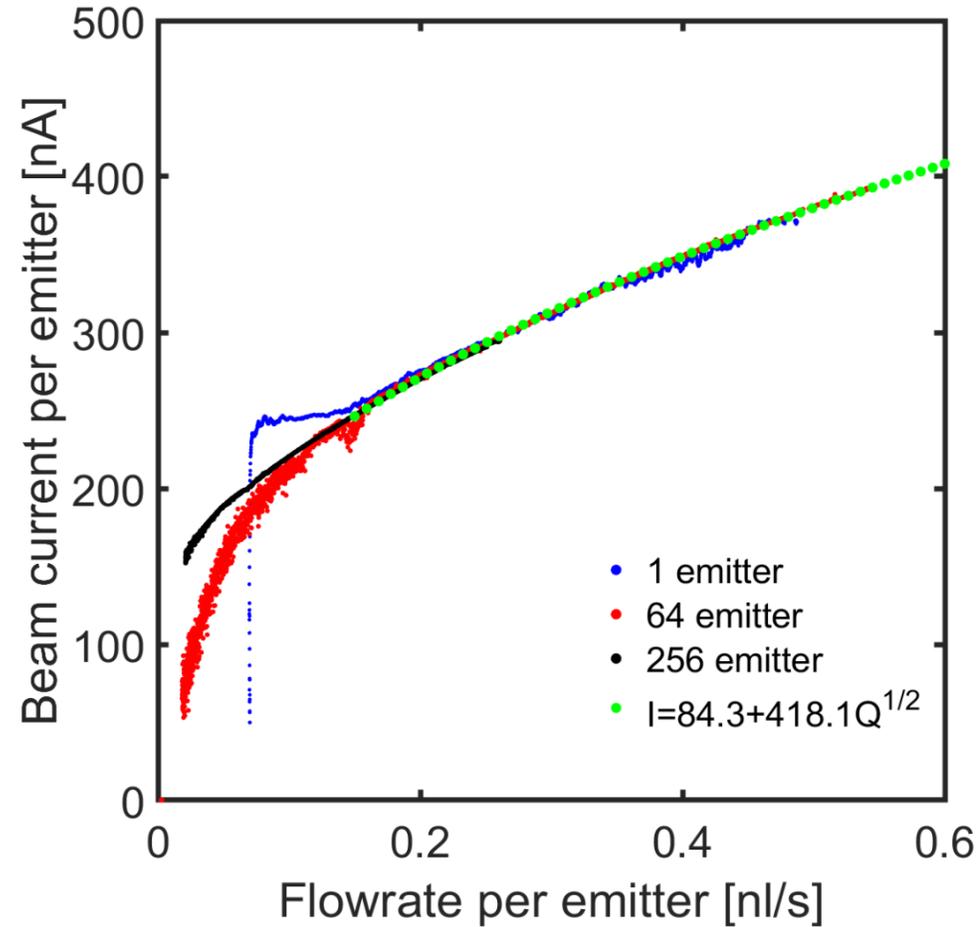




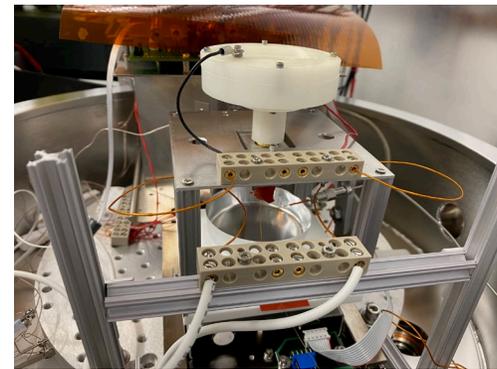
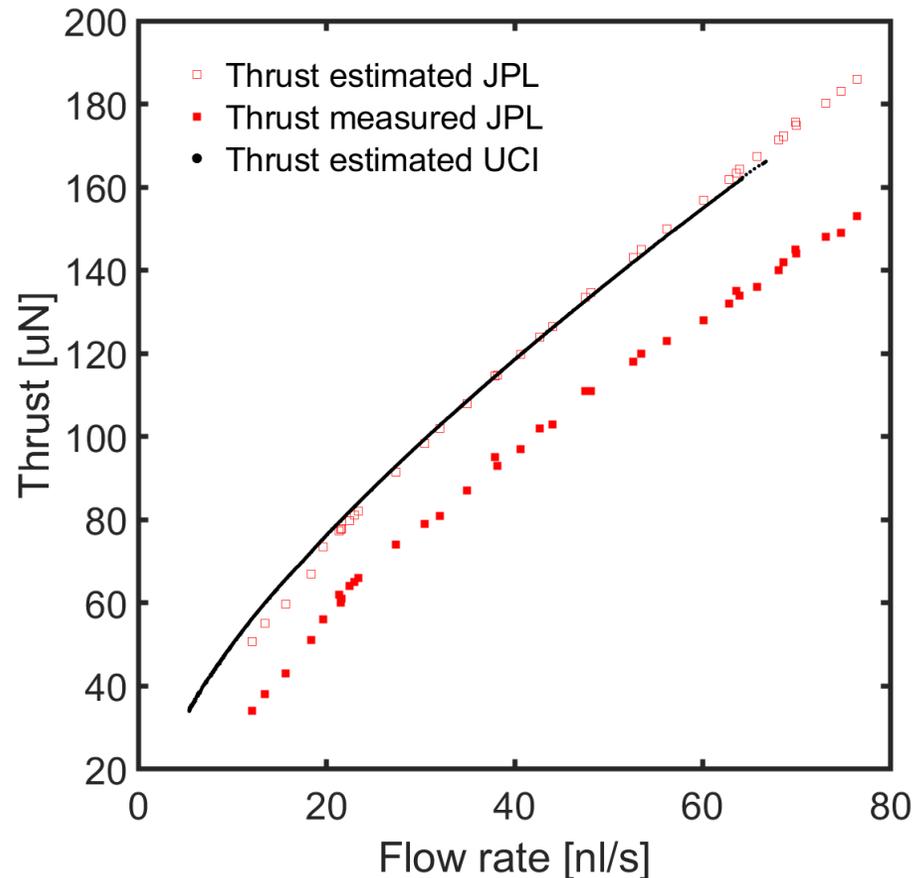
**Bonding of all wafers to produce a single, integrated thruster head with excellent emitter-extractor alignment**



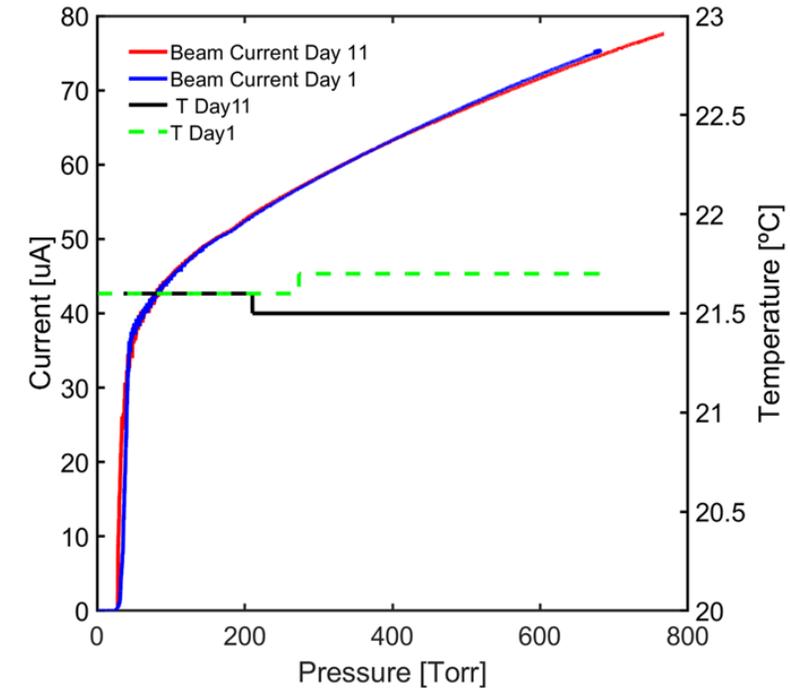
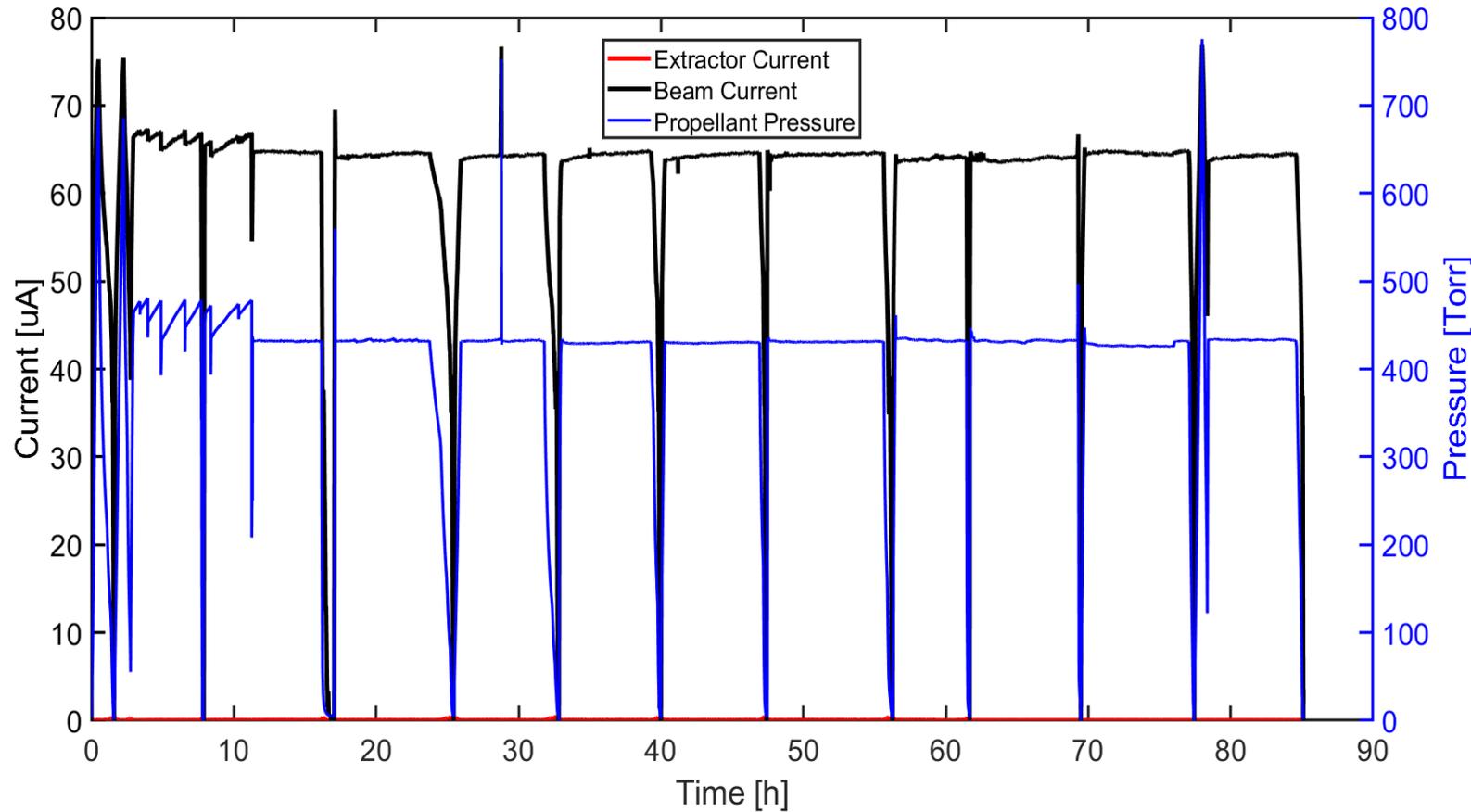




**every emitter is in the same operational state regardless of array size**



**direct thrust measurements (Dr. Colleen Marresse, JPL) compared to estimated thrust (based on beam voltage, current and mass flow rate)**

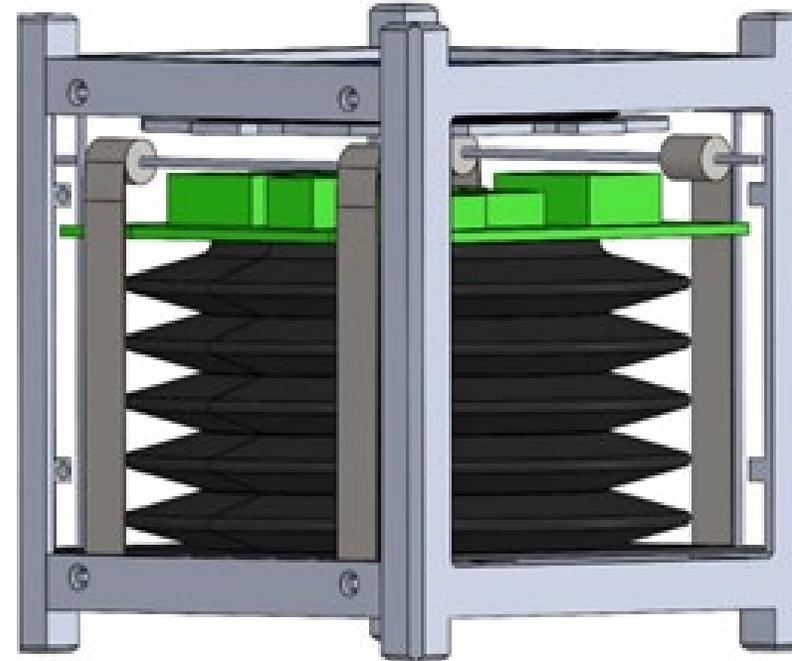
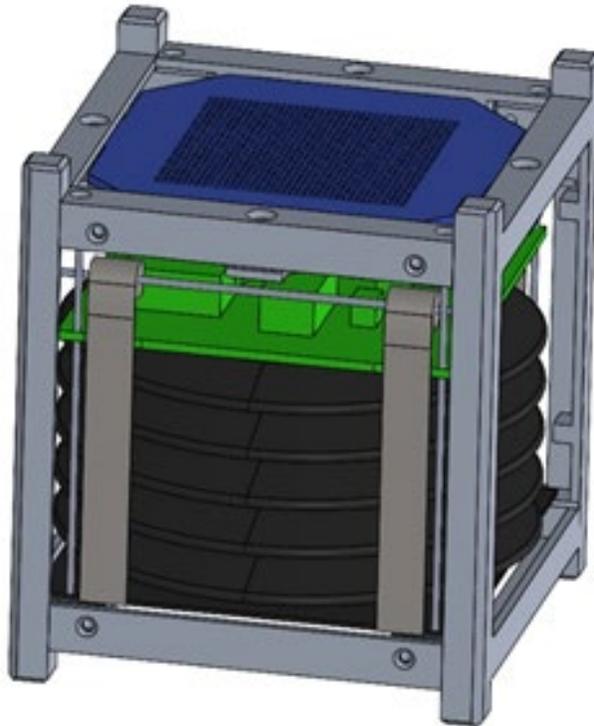


**86 hours of operation without change in performance. JPL is setting up a longer 1000-hour life test**



# Next Step: TRL 6 Demonstration

Demonstration of high-fidelity propulsion system (emitter array, propellant delivery system and PPU) in relevant environment



- 1U CubeSat propulsion system
- Bellows tank
- On-off microvalve
- Off-the-shelf components PPU
- Inclusion of accelerating electrode to increase  $I_{sp}$



# Thank You!

Electric Propulsion  
Laboratory **UCI**



Prof. M. Gamero-Castaño



Dr. A. Cisquilla-Serra



M. Galobardes-Esteban

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